

Radiant Glass Technology

E-glass Technology Designed to Enhance Performance of Window Glazing Systems, Solar PV, & Solar Thermal Panel Technologies

AC & DC Powered Technologies Compatible with Solar PV Power Systems for Providing Radiant Comfort while Increasing Energy Efficiency for Net-Zero Homes

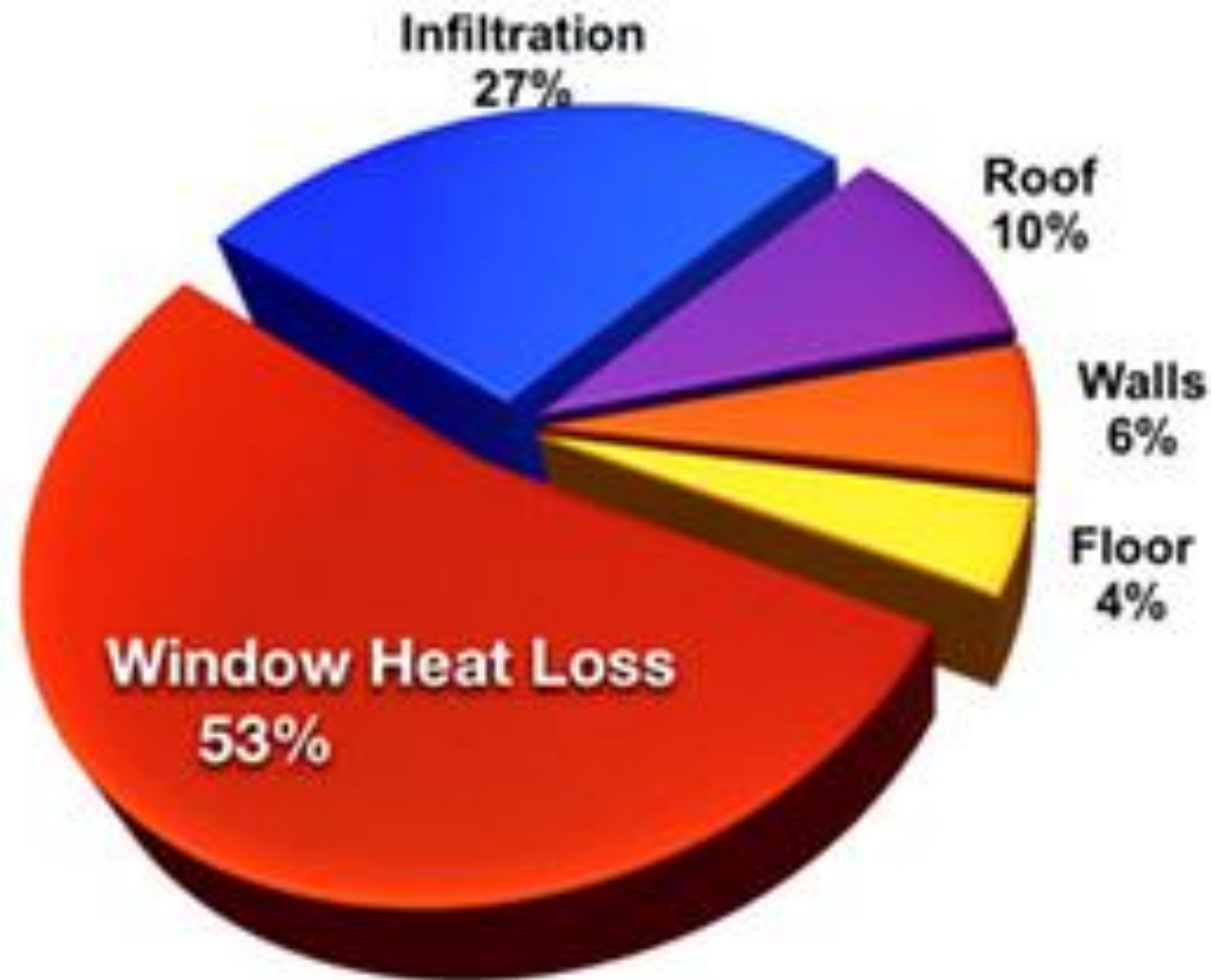
Addition of Radiant Glass

- Though not always required, the development of wider frames is ideal for addition of a radiant glass pane to existing window packages.
- The additional air or argon filled gap provides up to a 30% increase in thermal resistance, even for some passive window glazing packages that already contain up to 4 glazing units (e.g., two glass and two suspended film).

Reducing Window Heat Loss

- Heat loss from infiltration, walls, floor and ceiling/roof can be reduced by over 95% through insulated concrete form (ICF) technology.
- Hence, for passive house design with tight structures and superinsulation, windows and doors are the single greatest losses of energy.
- Efforts to achieve net-zero energy homes must focus on strategies that reduce energy loss from windows and thus eliminate cool drafts.

Conventional Window Heat Loss



Radiant Glass Technology

- In areas where heating requirements are significant, an innovative solution exists to counter the physical discomforts caused by windows – electrically heated windows or radiant glass technology.
- Initially, installing heated windows would appear inefficient from an energy standpoint since the initial perception is to think about the energy consumed by a heated window as being dissipated towards the outdoors.

Modeling Radiant Windows

- In order to examine the effects of an electrically heated window on a building's energy needs, a model has been developed and validated. The model is applicable to both conventional and heated windows.
- Compared to standard double-glazed windows, the model reveals that using heated windows actually reduces space heating and cooling loads.
- It also increases the thermal comfort in a building's perimeter zone by preventing cold temperatures on the indoor side of the window from occurring.

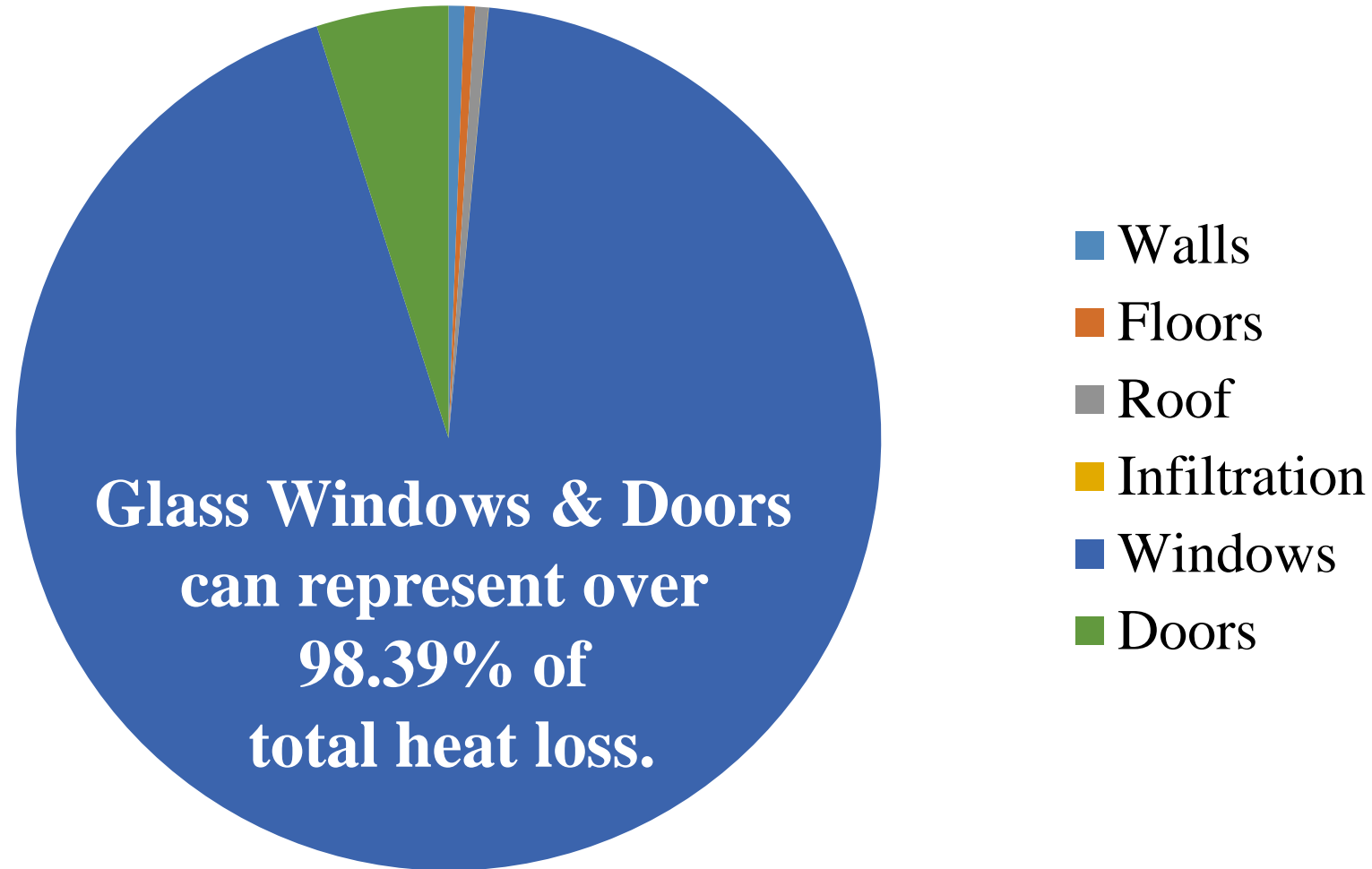
Radiant Window Strategy

- Compared to energy-efficient double pane windows, the study revealed a slight increase in the space heating load but a decrease in the needs for air conditioning.
- Furthermore, in cold climates and from an energy standpoint only, the results demonstrated that it is more advantageous to install a heated window on the north and east (or west) walls of a building as opposed to the south because, among other things, the solar heat gain coefficient (SHGC) of a heated window is lower than that of windows normally used in the building sector.

Radiant Window Technology

- If heat loss for windows can comprise over 50% of energy loss for a conventional structure, for a passive house heat loss from windows could potentially exceed 95% of total heat loss unless strategic SHG and HP windows are utilized.
- Using HP windows and radiant/smart window technology to reduce heat loss allows for reducing total HVAC requirements.
- This is well illustrated in passive house structures with less than 2 Btu/sqft/hr peak heating and cooling loads.

Passive House Glass Windows & Doors Heat Loss



Passive Window Technology

- High performance glazing systems and insulated window frames with state-of-the-art warm edge spacers and thermal breaks can become net-producers of thermal energy during the day.
- Balancing thermal resistance with solar heat gain and thermal mass is critical for passive structures.
- Modern glazing technology, improving thermal resistance of frames, reducing infiltration, and state-of-the-art installation using adequate foam products is required.

Advantages of Radiant Windows

- The heated window technology offers many advantages including comfort near the windows, no accumulation of condensation or frost, noiseless heating in perimeter zones, no maintenance, and the obvious fact that heated windows do not require additional space.
- These advantages are the main criteria that would motivate one to install heated windows in a building.

Energy Consumption

- There is a misconception that radiant glass/window technology increases a building's energy consumption.
- In direct contrast, a 2008 study conducted by the Hydro-Quebec Research Institute reveals that installing electrically heated windows on a building's perimeter does not necessarily incur an increase in energy consumed.

Strategic Installation

- Compared to standard double pane windows, research results reveal that using heated windows reduces the energy needs whereas, compared to energy efficient double pane windows, data reveals that heated windows incur a slight increase in energy consumption.
- Moreover, from an energy standpoint only, data reveals that it is typically more advantageous to install heated windows on the north and east (or west) sides of buildings rather than the south side.

10-15% Energy Savings

- The Hydro-Quebec research data is based solely on the energy balance occurring at the windows.
- These conclusions do not cover the different side effects associated with the use of heated windows that are also susceptible to having an impact on a building's energy consumption.
- For example, heated windows can allow for eliminating or sizing down perimeter heating in buildings. In this regard, it has previously been demonstrated that simply sizing down the conventional perimeter heating can result in savings of 10-15% on the total energy needs for heating.

Thermal Comfort at Lower Set-point Temperatures

- Heated windows also have an impact on the thermal comfort in a room.
- Indeed, the comfort equations show that the ambient temperature of a room with heated windows can be maintained at a lower level and still remain operationally adequate.
- In this regard, a lower set-point temperature reduces the overall energy losses that occur through the entire thermal envelope of a building by infiltration, ventilation and conduction during the heating season.

Radiant Window Modeling

- The side effects associated with the installation of electrically heated windows must be taken into consideration for a comprehensive evaluation of their real impact on energy needs.
- To further study the impact of heated windows on the energy needs of buildings, it would therefore be useful to incorporate the window model presented in the above study into a simulation model that includes more of the dynamics of a building beginning with conductive energy loss.

Conductive Energy Loss

- Be it poorly insulated or well insulated, the rate of conductive energy loss from any structure in cold climates is a function of the difference between outside and inside temperatures.
- Utility companies have long promoted the energy savings associated with lowering heating settings during sleep or non-occupancy.

Conserving Energy Using Radiant Temperature Zones

- Imagine the energy saved with an ability to be comfortable at 70 °F in the space that you currently occupy while the remainder of the house or office building is maintained at 10 to 15 °F cooler.
- This is possible with state-of-the-art radiant heating systems that supply warmth as needed by either room or zone.

Conductive Heat Loss

- Although radiant heating systems have been shown to be more efficient at heating people and space than gas heated forced air, it has generally been found to be inefficient or occasionally unable to deliver enough heat in the space near windows to provide adequate comfort.
- Dual-glazing, low-e, gas-filled, even triple-glazing have all successfully improved upon window conductive heat loss.

Body Heat Loss

- However, they do nothing for the heat that radiates from the body and continues out through the glass, leaving an individual cooler.
- While high performance glass slows conductive heat loss, even the best glazing still cools the interior air next to the glass.
- This cooled air then sinks and produces what feels like a cold draft even with a fixed picture window where air leakage is zero.

Conventional Low-e Film

- These comfort problems can only be overcome by making the glass as warm, or warmer, than the air around you.
- If small amounts of electricity are applied to the metal low-e film on conventional window glass, the glass itself can efficiently be raised in temperature to match or exceed that of the air in the structure.

Radiant Glass Efficiency

- Some studies have shown that it takes less electrical energy to maintain comfort through radiant glass in cold weather than it takes to power the furnace blower to move warm air into the window area, a method which is often less than adequate.
- In addition to the potential energy savings of radiant glass technologies, optimizing energy efficiency provides greater comfort for occupants.

Commercial Technology

- The radiant glass concept is not new. Forty years ago the refrigeration industry discovered that applying current to low-e film on glass consumes far less energy than that needed to replace refrigeration loss from opening grocery freezer doors to see what was inside.
- We can use this same technology to lower the average temperature in living space while improving our level of comfort in drafty areas near windows.

Radiant Glass Companies

- There are currently three radiant glass companies providing products in the US.
- However, only one of them (Energized Glass) uses conventional Low-e glass and it is substantially more affordable (as little as \$10/sqft in comparison with the other products priced at \$55/sqft or higher).
- Adding a heated window pane to existing windows can substantially reduce heat loss of existing windows while improving comfort.

Energized Glass

- Developments by EG in the last 3 years have dropped the cost of radiant glass technology by nearly 90% (\$269/window for the electronics only regardless of size) and have re-structured the components to work within nearly every window frame used today.
- Only independent verification by government entities of the energy savings potential outlined above stand in the way of private industry aggressively moving forward with these comfort and energy saving opportunities.

Energized Glass Technology

Energized Glass, LLC, located in Fort Collins, Colorado, offers warm radiant glass for greater comfort, zero condensation, and reduced use of HVAC systems:

- The world's first fully integrated, ETL certified heated glass window
- Condensation resistance rating of 100 with higher temperature settings
- Comfortable warm glass eliminates the need for forced air window wash
- Digital control temperature setting range up to 100 °F.
- Normal window installation with standard J box electrical connection
- Potential increased insulated glass longevity with reduced insulated glass unit (IGU) temperature swings

EG Radiant Window Controller Software

- Has been developed for custom configuration and temperature setting of each window via the use of a computer and MyFi wireless technology.
- The central control feature allows for instantly turning radiant windows on or off as desired.

Safety Tests

- UL and ETL standards include a safety test of all electrical elements, appliances and components that are made available to the public.
- Radiant windows are subjected to a "HiPot" (high potential) test wherein the unit is tested at over 1200 volts. This charge is more than ten times the normal line voltage.
- In addition, EG standards dictate a leakage of less than 5 mA under this test when industry standards are much higher at 50 to 100 mA.

Testing Energy Consumption

- The thermo efficiency of a window is referred to as its “U” value, which is the inverse of the more familiar “R” value.
- In other words, the lower the “U” value, the better the insulating properties of the glass.
- Energized Glass has performed significant empirical testing to determine the amount of energy consumed by its radiant window design.

Testing Energy Consumption cont.

- These tests were performed using relatively efficient double glazed thermopane windows with a glass “U value” of 0.33, and also using high performance triple glazed thermopane windows with a glass “U value” of 0.19.
- Typically in the window industry, only one pane of the thermopane unit has the transparent conductive oxide coating (TCO) coating.
- In the case of the Energized Glass product, two panes have a TCO coating for reasons of safety but only the inboard pane is energized.

TCO Coatings

- TCO is a doped metal oxide thin film predominantly used in optoelectronic devices, for example flat panel displays and photovoltaics (including inorganic and organic devices as well as dye-sensitized solar cells).
- Most TCOs are manufactured with polycrystalline or amorphous microstructures. On average, the aforementioned applications use electrode materials that have $>80\%$ transmittance of incident light as well as conductivities $>10^3$ S/cm for efficient carrier transport.
- TCO thin film coatings can increase the strength of glass by 80% and reduce cracking.
- TCO coatings are used for:
 - Low-e glass including architectural glass
 - [TCO for solar cells](#)

EG Testing Methodology

- An energized window was placed in the frame with the unheated pane facing into a freezer compartment where the temperature could be set to replicate predetermined exterior temperatures.
- The radiant heating pane was facing into the room area where the ambient temperature was maintained at $70^{\circ}\text{F} \pm 1^{\circ}$. This should closely replicate typical residential or commercial conditions in which radiant windows would be used.
- The amount of electrical energy required to maintain various inboard glass surface temperatures at eight different exterior air temperatures was measured precisely. The results of two of those inboard glass temperature settings are listed below.

Test Results

Without Window Washing

Test Chamber Temperature °F	Window Temperature °F	Watts/Ft ²	Test Chamber Temperature °F	Window Temperature °F	Watts/Ft ²
10	70	10	-10	100	24
0	70	8	0	100	23
10	70	8	10	100	23
20	70	7	20	100	20
30	70	5	30	100	19
40	70	4	40	100	18
50	70	3	50	100	15

Comparison of Energy Consumption With Window Washing

Test Chamber Temperature °F	Window Temperature °F	Radiant Glass Watts/Ft ²	Window Wash Watts/Ft ²
-10	70	10	6
0	70	8	6
10	70	8	6
20	70	7	6
30	70	5	6
40	70	4	6
50	70	3	6
60	70	1	6

Window Washing

- In cold climates, conventional construction methods control window condensation and achieve some measure of comfort near windows through “window washing”.
- The term “window washing” refers to the use of furnace fans or auxiliary fans and sometimes heaters, to blow warm air across the face of a window.
- This is done in an attempt to raise the temperature of the air near the window and counteract the chilling effect of heat loss that occurs through even the most efficient glazing.

Analysis

- The “window washing” approach to provide reasonable comfort has significant capital costs associated with it, including the cost of the motors and ducting to exterior walls.
- In addition, the motors consume energy at the same rate regardless of the outside temperature. Therefore, when the outside temperature is a relatively mild 50°, the fans continue to consume as much energy as at 10° F.
- The results from testing are identified as efficiency with and without “window washing.”

Window Washing Energy Consumption Comparison

- To compare the energy consumption of the radiant window verses a “washed” window we refer to ASHRAE 2005 Fundamentals handbook chapter 33.
- According to this standard, the floor supply air outlet should be 5 inches from the wall and discharge air vertically.
- The air velocity should equal 150 feet per minute to a level of 7 feet above the floor.

A typical outlet such as a Titus CT-PP-0 bar grille has the following performance characteristics:

Air Supply:	1770 CFM	External Static Pressure:	0.5 inches water
Motor:	0.75	Amps:	10.5
Voltage:	120	KW Demand:	1.26 KW
KW/LF Glass:	0.03559 KW/LF	Watts/LF:	35.5932

A typical blower motor such as a *First Co Fan Coil MB* has performance of:

Air Outlet Depth:	2 inches	Air Outlet Width:	48 inches
Throw @ 150 fpm:	7 feet	Flow Rate:	200 cubic ft/minute
Pressure Drop:	0.053	Flow Rate/LF:	50 CFM/LF

A standard 6 feet of glass height would result in a energy consumption of 5.9322 Watts/Ft² just to run the blower motor for “window washing”.

Calculating Energy Savings

- By comparing degree-day data for any specific geographic area, the kW savings can be projected. For Denver, CO it's estimated savings would be equal to 45,000 kWh's annually.
- A calculator is available on the www.Energizedglass.com website that enables inserting variable fan usage rates and energy costs specific to a location.

Energized Glass: 2013 Snow Melt Test



Snowmelt test set up:
Outside Air Temperature of
6°F, test began at 7:20 am.
Colorado snow accumulation of
2 inches on lower half of the
solar photovoltaic (PV) panel.

At 100% of power supply
capacity, the system was
drawing ~ 7 watts/ft²/°F/hr.

Energized Glass: 2013 Snow Melt Test cont.



At 7:40 am, 20 minutes after the radiant glass had been activated, 30% of the snow has melted.

Energized Glass: 2013 Snow Melt Test cont.



At 8:00 am all of the snow on the glass cover of the solar PV panel has melted. Total elapsed time is 40 minutes.

By 9:15 am all of the moisture has evaporated from the glass cover of the solar PV panel. Total elapsed time is ~2 hr.

Power*e Glass Technology

- Power*e Glass solves the window heat loss problem by using a safe electric current to increase the temperature of the entire inside glass pane of windows and partitions.
- By increasing a window's temperature, Power*e Glass heats and insulates - stopping heat loss at the point where it occurs.

Radiant Glass Windows

- Power*^e Glass windows are enhanced industry standard two pane insulated glass units that dynamically create an efficient thermal barrier at the windows.
- Independent tests show that a Power*^e Glass heating system:
 - Provides better thermal comfort than other heating systems
 - Uses substantially less power than conventional heating systems.

Advantages of Radiant Windows

- Power*Glass is a green technology that can save power and money. By eliminating or reducing heat loss, Power*Glass can:
 - Reduce the need for other heating systems
 - Reduce the energy used for heating
 - Reduce heating costs
 - Enable lower room air temperatures
 - Eliminate condensation and fogging on windows

Proven Window Technology

- The Power*e concept is simple. At its core, Power*e Glass is a proven industry standard double paned window. By touching the glass pane, you can feel the warmth of the thermal barrier created by the Power*e Glass.
- However, the electric current flows safely and invisibly without wires across the metal coating on the other side of the glass pane where it cannot be touched.

Patented Design

- The unique patented continuous glass/metal contact of the Power*e Glass efficiently heats the glass.
- As a result, Power*e Glass uses less power and is more robust than other systems.
- It actually conserves about 85% of the energy, reflecting it back into the structure.
- It operates on DC power, revealing that it can eliminate the 15% loss for DC to AC inverters typically required for solar PV power systems.

Radiant Heat Technology

- Like the light from a lamp, Power*e Glass windows quickly cast a warm heat that is absorbed and re-radiated until all of the occupants and room surfaces become evenly comfortable.
- Power*e Glass windows provide comfort at lower room air temperatures by increasing the radiant heat in the room. You truly can feel the heat from the Power*e Glass. It works by directly warming you and other objects in the room - not by heating the air.
- Additionally, heated Power*e Glass stops all of the heat otherwise lost through the windows from the interior - essentially giving Power*e Glass windows a higher R-value than other windows.

Insulation, Heat & Comfort

- Power*_e Glass provides insulation, heat and comfort. Buildings are heated to offset heat loss which occurs primarily through the windows.
- By raising the Power*_e Glass temperature above the room air temperature, this heat loss is rendered to almost nothing. Thus heat loss calculations can be simply changed accordingly.
- By further raising the Power*_e Glass temperature, Power*_e Glass can provide additional heat and comfort to building perimeters and other areas where more heat and comfort are desired.

Simple Construction

- Power* Glass windows look like ordinary double paned windows and can be washed and treated like ordinary windows.
 - Power* Glass windows use only two glass panes to provide better heat and insulation.
 - Other "energy-efficient" windows use complex designs combining gases, three or more glass panes and/or plastic films. Inevitably, these gases leak, and the additional glass panes and films increase the likelihood of failure.
 - Temperatures can be controlled by conventional thermostats and other building climate control systems.
 - Power* Glass windows are sealed against moisture.
 - Power* Glass windows have no fans, air handling equipment or moving parts to break and no water lines buried in the foundation, walls or ceilings to leak.

Power*e Box

- The Power*e Glass is powered by the Power*e Box AC or by a low-voltage DC power supply.
- Using 120 VAC, each Power*e Box AC can power up to three Power*e Glass windows or units and may be located nearby or remotely from the Power*e Glass.
- Although typically 35 sf or smaller, these Power*e Glass units may be 50 sf or larger depending upon glass sizes, available power supplies, and heating requirements.

Power*e Box cont.

- A Power*e Box AC operates in either Thermostat Mode or in Glass Temperature Mode.
- In Thermostat Mode, a standard thermostat monitors the air temperature of the room and turns the Power*e Box and Glass off and on as needed.
- In Glass Temperature Mode, a Power*e Box AC monitors and keeps each Power*e Glass unit at one of three preset target temperatures (low - medium - high).
- The target temperatures are designated by the customer, and the target temperature for each Power*e Glass unit may be separately changed as required.

Radiant Window Tests

- Independent tests have consistently shown that heated windows do not lose more heat or power to the outside as outside temperatures become colder.
- That is, heated windows do not lose their efficiency as the weather becomes colder due to the insulating effect of the heated glass, the relative heated glass temperature and the lower room air temperature, the low-e glass coatings used, the air gap between the glass panes and other factors.

Radiant Window Tests cont.

- In 2007 and 2008, Kansas State University (KSU) tested the Power*^e Glass using their climate chambers and computer simulations and found comparable results.
- This radiant glass methodology has been validated in more than six ASHRAE research projects over the last 15 years, the DOE ENERJOY case study and numerous additional energy management studies reported in ASHRAE symposiums, papers and articles.
- ABOVE is unique as a dynamic program that may be used to accurately model building design, space by space, in addition to standard envelope HVAC sizing.

Radiant Window Tests cont.

- For the purposes of this particular study, the students at KSU modeled a room that was 14 ft. long by 10 ft. wide, with a ceiling height of 9 ft. The room had one window in it, and the window was sized at 5 ft. high by 6 ft. wide.
- The R values that were modeled were R-12 for the walls, no heat loss for the ceiling or the floor (centrally located on the middle floor of a three-floor building) and R-3.85 for the window. The model was exposed to operating temperatures of 10°F and 20°F outside, maintaining 70°F inside.

Radiant Window Tests cont.

- What was found was that with an operating temperature of the glass at 123°F, the mean radiant temperature in the room was an average of 71.6°F compared to 66.6°F for the forced air system.
- This means that the human comfort factor was positively affected by the presence of the warm window surface, and the normal negative effect of a cold window on human comfort was completely avoided.

Radiant Window Tests cont.

- As for thermal operating efficiency, the window was compared in operating wattage to maintaining a good human comfort factor against a forced air heating system.
- Basically stated, the application of the heated window system in the model the students developed resulted in a net reduction of energy Btu/hr. to the tune of 92% of the room's heat loss before the introduction of the radiant window.
- Though results may vary, the potential for reducing energy consumption of a given building by eliminating the basic window conductive losses are typically around 25% to 50% and more depending upon the building's glazing ratio to square footage ratio.

Radiant Window Tests cont.

- The building's conductive losses, infiltration losses and the typical duct losses associated with the operation of a forced air system all are lowered through the use of the heated window, as was proven by the ABOVE study performed by Kansas State University.

2007 Radiant Window Tests

- Among their findings KSU concluded that Power*^e Glass windows:
 - Substantially reduce the need for other heating systems.
 - Produce more consistent and comfortable room conditions than natural gas forced air heating.
 - Direct 85% of their power to heat the interior - regardless of outside temperatures.
 - Stop virtually all building heat loss through the heated glass.
 - Create heated zones that complement other heating systems by reducing a building's heat load.

2008 Study

- Using the 2007 information and other data, KSU's 2008 study used an ABOVE computer simulation of a multistory Chicago office building to compare a natural gas heating system and a Power*e Glass system.

Custom Made

- Made to the customer's specifications, Power*e Glass can be combined with clear, tinted, patterned, opaque, laminated or other glass and may be incorporated into industry standard wood, vinyl, fiberglass, metal frames or other custom enclosures.
- Power*e Glass may be used in new construction or as part of building remodeling.

Radiant Glass Applications

- Power*Glass units can be used as windows, glass walls and panels, and glass divider walls for cubicle conditioning in the core of the building.
- Power*Glass units can be integrated into windows, walls, interior partitions and other architectural products and can be installed into new construction or retrofitted into existing buildings.

Operating Parameters

- The maximum Power*e Glass temperature is 130°F.
- A Power*e Box AC operates in either Thermostat Mode or in Fixed Temperature Mode. In Thermostat Mode, a standard thermostat monitors the air temperature of the room and turns the Power*e Box and Glass off and on as needed. In Fixed Temperature Mode, a Power*e Box AC monitors and keeps the Power*e Glass at a preset temperature.
- Power*e Glass DC typically operates between 85°F and 100°F.
- The Power*e Glass warm-up time from power off is typically 10 minutes or less.

Power*e Glass Units

- Standard Power*e double paned insulated sealed window manufactured by Radiant Glass Industries LLC incorporating Pilkington TEC-15™ tempered low-e safety glass (inside glass pane) and any tempered clear, tinted, patterned, opaque or other glass (outside glass pane).
- Typical maximum glass size is 35 ft². Larger sizes are available by special order. Overall unit thickness can be specified from 5/8 inches (15.875 mm) to 11/16 inches (26.9875 mm).
- Power*e Glass units are sealed using a reactive hot melt butyl sealant. All electrical heating components are sealed within the unit except for electric and control wires that extend from one corner of each unit to the Power*e Box AC or DC power supplies.

Power*e Box

- Power*e Glass may be powered by 120 VAC Power*e Boxes or by low-voltage DC power supplies.
- A Power*e Box AC may power up to three Power*e Glass units.
- A DC power supply may power up to several Power*e Glass DC units depending upon their size and power needs.
- In Thermostat Mode, the Power*e Box AC and Glass is controlled by any standard thermostat or building system.
- In Fixed Temperature Mode, a Power*e Box AC monitors and keeps the Power*e Glass at a preset fixed temperature.
- A DC power supply typically monitors and keeps the Power*e Glass DC at a preset temperature.
- Power supplies sized to the Power*e Glass are required.

Safety Features

- Power* systems incorporate a number of safety features including tempered glass, automatic glass temperature monitoring and automatic power cutoff for excessive operating temperatures or glass breakage.